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Comment on gi-2021-34

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Author comment on "The soil heat flux sensor functioning checks, imbalances' origins, and forgotten energies" by Bartosz M. Zawilski, Geosci. Instrum. Method. Data Syst. Discuss., https://doi.org/10.5194/gi-2021-34-AC2, 2022

First of all, I would like to thank L. Montagnani for referring my paper, for his remarks and criticism that help me to improve this paper.
I will answer all the raised points after the second referee rapport; however, I would like to answer here one point that seems to me to be the most important expressed criticism.
RC1: "Another point on which I disagree is the use of the annual sum of G as a benchmark if is close to zero. This leads for example, to the suggestion of the removal of geothermal energy. In my view, all the soil heat flux plates located in the footprint of an eddy covariance tower should be representative of the actual energy flow and not corrected. I would place the sensors on the shade, in the partial shade and in full sun since the scope of the measurement is to assess the average value of the selected variable and its standard deviation"

I do agree with the point that all the plates *should* be representative of the *actual* energy flow. Unfortunately, in some cases, they are not because they can not be. Eddy covariance footprint is much larger than the SHFP area then, in a case of not-perfectly homogeneous soil, only one SHFP cannot represent overall soil heat flux for the eddy covariance measurements but, in the best case, the overall measured soil heat flux when SHFPs are located in the eddy covariance footprint which is far to be always the case. I think that one of the crucial points was not clearly expressed in my original paper. Indeed, all inhomogeneities are causing non-vertical heat fluxes which give rise to the SHFP measurements imbalances only on the boundary of these inhomogeneities and the real, overall perturbation is nil. We can see it as energy conservation. In other words, any inhomogeneity may perturb the local SHFP measured heat flux balance bat not the overall heat flux balance in the area containing this inhomogeneity. Depending on which side of the boundary of the inhomogeneity is placed the SHFP, its measurement balance will be positively or negatively influenced. In my mind, "adequately measured inhomogeneity" is then an inhomogeneity with SHFP placed on each side of the boundary giving overall measurement exempt of the inhomogeneity boundary influence because the real, overall heat flux is not imbalanced. Theatrically speaking it is possible to "adequately measure" all inhomogeneities with numerous SHFP but in piratic it is not evident to know where are the boundaries. Using numerous randomly placed SHFP, the probability of valid representability is rising but this point is not guaranteed in any way and has to be checked. With only one-dimensional measurements, it is difficult if not impossible to correct any SHFP measurements in respect to the non-representability of the overall measurement. The only way that I can see is to discard one or more implicated SHFP if their imbalances are too far from the overall measurement imbalance. It would be possible

to investigate closer SHFP measurements with 3D fluxes measurements but it is not yet the case. With vertical and non-vertical heat fluxes measurements inhomogeneities influence could be better delimited. This statement was added to the text. With the new overall measurement calculated using only approved SHFPs, a missing soil heat flux, see next point, can be assessed. Please, note also that we are placing the SHFP horizontally, assuming a one-dimensional flow, which means that only the vertical heat flow is measured. This assumption is no more valid in the case of shallow non-vertical heat exchanges, it means in the case of shallow inhomogeneity boundary presence. In this case, the SHFP measurement is no more representative of the actual energy flow. What is representative is the overall SHFPs' measurement with SHPS placed on both sides of the inhomogeneity boundary and this has to be checked. For example, using my scheme of three plates with one under a tree shade (Fig. 3): supposing that the plates are measuring the real heat flux. If plate C (under shadow) is placed symmetrically to plate B, it means that its imbalance is opposite to the plate B imbalance, then the overall heat flux imbalance is nil, as it should be because the imbalance of the real, overall heat flux present on the considered surface is nil. Now, supposing that we have only two plates, not three plates, installed on the same surface. If it is plate A and plate B, then the overall heat flux imbalance will be negative. If it is plate A and plate C, the overall heat flux imbalance will be negative and, if it is plate B and plate C; the overall heat flux imbalance will be nil. Using annual integration, we can see immediately that plate A does not have any inhomogeneity boundary in the vicinity and that plate B and plate C are "symmetric". In the case where only two plates are used, by individual integration we can see if the inhomogeneity boundary is present and was correctly compensated by placing as many plates on one side as on the other side. Of course, the reality is a bit more complicated since not only one inhomogeneity may be present, and not only inhomogeneities causing imbalances.
Second point: SHFP can only measure the conductive heat exchanges, and the resulting heat flux measurement does not represent the total, real heat flux. Geothermal heat flux is sensed by the plates and corresponding subtraction is suggested for unbalance check by annual integration. Integration of SHFP's measurements allows us to compare their behavior rapidly. In the case where all of the SHFP, as it is on FR_Lam and FR_Aur presents roughly the same G imbalance, we may reasonably assume that the special variability is not responsible for it. Then, the possible corrections do not concern natural inhomogeneities boundaries but rather the missing measurements. For a better explanation, I am adding an appendix with a simple scheme of a soil column along with a short comment. Please see the attached pdf for the corresponding scheme and formulas.

RC1: L49" 'biased by inhomogeneities'. As mentioned above, I believe that all inhomogeneities should be adequately measured in proportion to their contribution to the overall flux."

This point is effectively similar to the previous one raised at the beginning of RC1 comments. Again, the inhomogeneities are not influencing the overall measurement imbalance but only influencing measurements imbalances of SHFP installed close to the inhomogeneities boundaries. The target is not to correct the concerned measurements but to check that we have as many positively influenced SHFP as negatively influenced SHFP and to discard if any, obviously biased SHFP without a "symmetrically" installed SHFP for overall heat flux calculation. This is suitable for later missing soil heat fluxes assessment.

As mentioned previously, with a preserved soil temperature profile and preserved specific heat profile after one year, the overall flux integration should be nil, by definition. But it is true if, and only if, the plates emplacements are representative it means if SHFPs are placed to counterbalance inhomogeneities deviations as each inhomogeneity give rise to a positive imbalance in one emplacement and a negative imbalance in an adjoining emplacement the sum being nil by energy conservation. If not, the annual integration of the overall measurement is not nil and the main problem is then the measurement

representativity We cannot talk anymore about adequately measured inhomogeneities. Moreover, fatally, we never know in advance if plates are adequately measuring each inhomogeneity in proportion to their contribution to the overall flux. Statistically, the more SHFP we are placing, the better is the chance to get representative measurement but it is not guaranteed. For these reasons, an annual integration of each SHFP measurement and the overall measurement gives us a quick idea about each SHFP representability and overall missing heat flux measurements.

Please also note the supplement to this comment:
https://gi.copernicus.org/preprints/gi-2021-34/gi-2021-34-AC2-supplement.pdf